growing ALFALFA

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GROWING ALFALFA [1]

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ALFALFA is one of the most palatable and nutritious crops grown for forage in the United States. The hay is rich in proteins, minerals, and vitamins, besides being low in fiber. These excellent feeding qualities, together with high yielding ability, make alfalfa one of the most valuable forage crops for hay and for dehydration. Alfalfa also is used for pasture and is a highly effective cover crop for preventing soil erosion.

The alfalfa plant is a herbaceous perennial legume belonging to the same family as peas, beans, and clover. Its flowers are borne in loose bunches, or racemes, and are mostly of a purplish color. The pods in which the seed is produced are twisted spirally in one or two turns, similar to the shell of a snail. Each pod contains several small kidney-shaped seeds.

The stems, which are usually not more than ⅛ inch in diameter, are erect and commonly reach their maximum height of several feet at the time of blossoming. The semiwoody base of the plant, known as the crown, gives rise to new stems every 4 to 6 weeks throughout the active growing season. This makes it possible to take several cuttings of hay during the year. The root system is characterized by a distinct taproot, which in permeable soil may extend 30 feet or more in depth. The taproot has few to many branch roots. The leaves are in threes, like clover, and are arranged alternately on the stem.

It is generally believed that alfalfa originated in southwestern Asia, though forms from which it might have developed are found in China and Siberia. Historical accounts indicate that it was first cultivated in Persia. From there it was taken to the Mediterranean countries and finally to North and South America. The first recorded attempt to grow alfalfa in the United States was made in Georgia in 1736. It was not until about 1850, however, when Chilean alfalfa was brought to California, that the crop proved successful and began to be grown widely. Since then its culture has spread throughout the country.

The total national acreage devoted to alfalfa has shown a continual upward trend. This trend was rapid between 1899 and 1919 when acreage doubled each 10 years. From that time until recently the land area in alfalfa has increased at a slower rate; the 13,000,000 acres occupied by this crop in the early 1930's increased about 1,000,000

[1] This bulletin is a revision of previous editions prepared by H. M. Tysdal and the late H. L. Westover.

[2] Acknowledgment is made of helpful suggestions received from C. S. Garrison on the section "Seed" and of assistance by K. W. Kreitlow in the preparation of the section "Diseases."

acres every 5 years until 1948. Since then the increase has been at a rate of approximately 1,000,000 acres each year.

This recent stepped-up trend in expansion of alfalfa acreage may be attributed to improved varieties which have greater stand-persistence qualities, and to the use of better fertilizer and soil-management practices. The importance of the latter applies especially to the eastern part of the United States where alfalfa once failed over two centuries ago for reasons unknown at that time, but presumably because of deficiencies of one or more of the major and minor mineral elements.

The most important alfalfa-producing States are Wisconsin, Minnesota, Nebraska, Iowa, Michigan, Kansas, and California. Total acreage of the crop in these States ranges from approximately 1,000,000 in California to about 2,000,000 in Wisconsin.

Average annual acre yield of alfalfa hay in the United States is about 2.25 tons. The yields vary considerably from State to State because of differences in length of growing season, and soil and moisture conditions. In general, the highest average production per acre is in those States where most of the crop is grown under irrigation. California, for example, has averaged more than 4 tons per acre annually for several years, with individual farms in the southernmost part of the State producing more than 8 tons per acre.

Old Types and Varieties

The commercial types and varieties of alfalfa developed and introduced into the United States consist of (1) common alfalfas; (2) the variegated group, including the varieties Grimm, Cossack, Baltic, Canadian Variegated (also known as Ontario Variegated), Hardigan, and Ladak; (3) the Turkistan group, including commercial Turkistan, Hardistan, and Orestan; and (4) the nonhardy Peruvian alfalfas.

Until about 1950, common alfalfa comprised the greater part of the alfalfa grown in this country. The seed from the various States or sections is usually designated by the name of the State in which it is grown. In Arizona and California, common alfalfa is frequently referred to as Chilean alfalfa because of its early origin in that country. Common alfalfa varies considerably in winter hardiness and other characteristics, depending on the conditions under which it has been produced. When it is grown for several generations in the North, it becomes more resistant to winterkilling as a result of natural elimination of the less hardy plants. In purchasing common alfalfa seed, therefore, an effort should be made to obtain it from a source where the winters approximate in severity those where the seed is to be sown.

In the southeastern United States, seed of common alfalfa grown in the latitude of Kansas and Oklahoma generally has given larger yields of hay and for this reason is usually more desirable than seed produced in the Northern States. All common alfalfas tested have been susceptible to bacterial wilt.

The alfalfas of the variegated group are generally recognized as being hardier than the common alfalfas. They are the result of natural crossing between the well-known purple-flowered alfalfa (*Medicago sativa*) and the yellow-flowered species (*M. falcata*). They owe their superior hardiness in part to the presence of the yellow-flower

parentage in their ancestry and in part to the natural mass selection that has taken place under the severe climatic conditions to which they have been subjected. The variegated alfalfas are of greatest value in the Northern States, where the winters are severe. Southward, where winterkilling generally is not a factor, certain strains of common alfalfa will ordinarily give somewhat larger yields, and the seed is usually cheaper.

Grimm alfalfa is the best known and until recently was the most extensively grown variety in the variegated group. It was brought to this country from Germany in 1857 by Wendelin Grimm and was grown for several years in Minnesota before public attention was called to its superior hardiness. Owing to its cold resistance, culture of this variety is confined largely to the northern half of the United States, where the winters are severe. Because of its susceptibility to bacterial wilt its use has declined where this disease is destructive.

Cossack alfalfa was introduced into the United States from Russia through the efforts of the United States Department of Agriculture in 1907. In tests this variety has given results comparable to Grimm alfalfa, but it is grown on a much smaller scale. It appears to be slightly less susceptible to wilt than Grimm.

Baltic alfalfa takes its name from Baltic, South Dakota, near which it was grown for several years. In yield and adaptability this variety compares favorably with Grimm but it has not given evidence of being superior. It has not been extensively grown, and the seed supply is rather limited. Like Grimm it is susceptible to wilt.

Canadian, or Ontario, Variegated alfalfa is similar in appearance and adaptation to Grimm alfalfa. In the northern humid States it has given results comparable to Grimm, but in tests in the northern Great Plains it has not appeared quite so productive. Practically all of the seed sown in the United States is produced in Canada. Canadian Variegated alfalfa is susceptible to bacterial wilt.

Hardigan alfalfa is a selection from Baltic made by the Michigan Agricultural Experiment Station for superior hay and seed production. In some tests in the humid Eastern States it has been somewhat more productive than some of the old variegated alfalfas, but it is not superior to them in cold resistance. It is susceptible to bacterial wilt.

Ladak alfalfa was imported by the United States Department of Agriculture from northern India in 1910. It has given excellent results in the northern Great Plains. It is hardier than other alfalfas of the variegated group and has the further advantage of being somewhat resistant to bacterial wilt. Ladak also has an unusual capacity of going dormant during prolonged periods of summer drought and reviving in growth when moisture conditions again become favorable.

Turkistan alfalfa was introduced into the United States in 1898, and at one time most of the imported seed came from Turkistan. In recent years, however, there have been no commercial importations of Turkistan seed. Turkistan alfalfas vary in their reaction to cold and bacterial wilt, but recent tests indicate that seed from the most important seed-producing districts in that country is generally equal or superior to Grimm alfalfa in hardiness, and is also resistant to bacterial wilt. In numerous tests in various parts of the United States, Turkistan alfalfa has usually been less productive than some of our domestic alfalfas. It has given fairly good results in the central and northern Great Plains where wilt is a problem. In the East and

South, however, Turkistan alfalfa has been very unsatisfactory, owing to its tendency to become dormant early in the fall, and its susceptibility to yellowing and to certain leaf diseases that result in shedding many leaves before the plants have reached the most desirable stage for harvesting.

Hardistan is the name given by the Nebraska College of Agriculture to an alfalfa that is undoubtedly of Turkistan origin and that first attracted attention by its apparent resistance to wilt and cold. It is very similar to some of the better commercial importations from Turkistan as regards resistance to cold and wilt, susceptibility to leaf diseases, tendency to early dormancy, and productivity. Although the variety is promising where wilt is prevalent in the upper Mississippi and Missouri Valleys, tests indicate that it is not likely to prove more satisfactory in the East and South than most of the commercial lots from Turkistan. The seed supply is at present very limited and, like Turkistan, it is being replaced by more productive, wilt-resistant varieties.

Orestan is the name applied to a Turkistan alfalfa that has been increased from an introduction in 1929. In early tests in eastern Oregon, this alfalfa appeared to be somewhat superior to other Turkistan introductions made at that time. It appears to be equal in wilt resistance to the best alfalfas from that source but has given no indication of being better adapted to eastern humid conditions. This variety is also being replaced by improved disease-resistant types.

Peruvian alfalfa is the least hardy and most rapid growing of our commercial varieties. It was introduced into the United States from Peru in 1899. It seldom survives winters where the temperature falls below 10° F. and is therefore suited only to the extreme South and Southwest. Where it survives the winters, Peruvian alfalfa gives somewhat larger yields than most other varieties. Two strains of Peruvian alfalfa are recognized, the smooth-leaved Peruvian and the hairy Peruvian. The Chilean is similar in many respects to the smooth Peruvian and is widely used in the Southwest.

New Varieties

Several new alfalfa varieties, the result of intensive breeding research, have been introduced in the United States since 1940. Seed is now becoming widely available for most of them. The 11 most promising varieties are Ranger, Buffalo, Atlantic, Williamsburg, Narragansett, Vernal, Nemastan, African, Indian, Caliverde, and California Common 49. The wide ranges of adaptability for the first three varieties listed are shown in figure 1. The other varieties are adapted in more limited areas, or have not been tested sufficiently to establish their regions of adaptation.

Ranger, originated by the Nebraska Agricultural Experiment Station and the United States Department of Agriculture, is resistant to the bacterial wilt disease, and is also relatively cold resistant (fig. 2). It is therefore adapted to the Northern, Central, and New England States. Enough seed of Ranger is available to meet the demand for a wilt-resistant, winter-hardy variety.

Buffalo is also highly resistant to bacterial wilt. It was developed from Kansas Common by the United States Department of Agriculture and the Kansas Agricultural Experiment Station. The range of

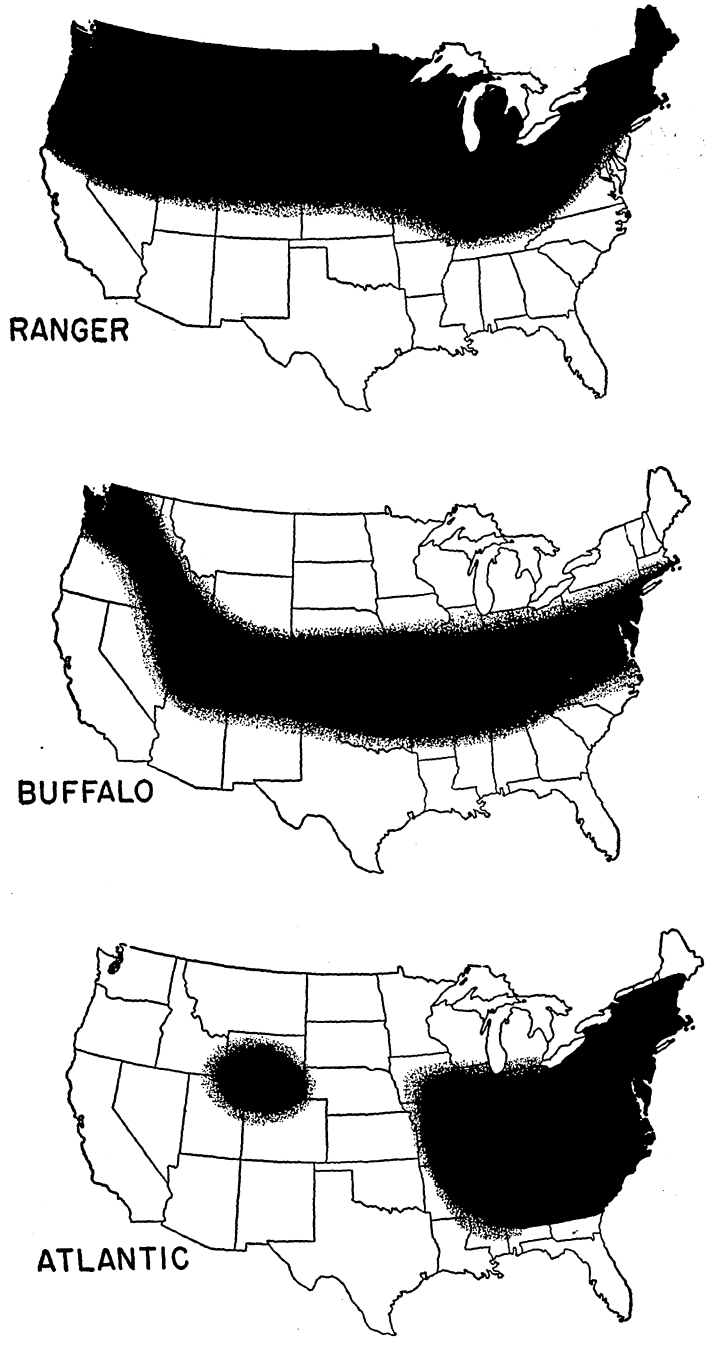

Figure 1.—Regions of adaptation of Ranger, Buffalo, and Atlantic alfalfa.

Figure 2.—Wilt resistance in 5-year-old alfalfa: Ranger at left, Grimm at right. (Courtesy of the Minnesota Agricultural Experiment Station.)

adaptation of this variety overlaps that of Ranger at its southern limit and extends somewhat farther south. Buffalo seed is now available in sufficient quantities for planting in areas where it is adapted.

Atlantic, a high-yielding variegated variety from the New Jersey Agricultural Experiment Station, is well adapted in the Eastern States, and has been successfully grown in Wyoming and northern Colorado. It is somewhat tolerant, but not resistant, to bacterial wilt and therefore should not be used where this disease is a serious problem, if longtime stands are desired. Seed of Atlantic has been increased rapidly during the past several years and is now generally available.

Williamsburg is a Virginia selection from Kansas Common. Under eastern Virginia conditions, it is more persistent and competes better with summer weeds than most varieties. It is being tested in many States, but the seed supply is limited.

Narragansett has been a high-yielding strain in Rhode Island, where it was developed. This variegated variety equals Ranger and Grimm in winter hardiness and exhibits extreme decumbent growth during fall. It is susceptible to wilt, but is promising where the disease is not prevalent. The seed supply is increasing rapidly and seed is now available commercially.

Vernal, a variegated, bacterial wilt-resistant variety, was developed by the Wisconsin Agricultural Experiment Station in cooperation with the United States Department of Agriculture. It is equal or superior to Grimm in winter survival. Hence, its greatest value probably will be in those Northern States where wilt is a problem and winter conditions are severe. The variety is being tested in many States, and seed stocks are being increased rapidly.

Nemastan, introduced from Turkistan by the United States Department of Agriculture, is resistant to the stem nematode. It is

usually planted only in Utah and Nevada where this pest is prevalent. It is highly susceptible to the leaf spot diseases. Where the stem nematode is not present Nemastan does not yield as well as some other adapted varieties. The Nevada Agricultural Experiment Station and the United States Department of Agriculture are developing new strains which have resistance to both bacterial wilt and stem nematode.

African, selected from an Egyptian introduction by the United States Department of Agriculture, is a rapid grower that recovers quickly after cutting. It is suited to the deep Southwest, and is not hardy in the Central or Northern States. Seed is now available in Arizona and southern California.

Indian, now being used in the Southwest, was introduced by the Department of Agriculture from India. This variety resembles African in that it is not hardy enough for central and northern areas. Seed of Indian is available locally in the Southwest.

Caliverde is highly resistant to bacterial wilt, common leaf spot, and mildew. It was developed in California by crossing California Common with a Turkistan selection and backcrossing to California Common. Caliverde is identical to California Common in growth habit, recovery after cutting, and winter-hardiness. In the absence of disease, there is no difference between the two varieties in yield. Caliverde is adapted to areas in the Southwest where winterkilling is not severe. Seed of this variety became available commercially in the fall of 1952.

California Common 49 was developed by the California Agricultural Experiment Station for tolerance to the dwarf virus disease. It was selected from California Common and, except for dwarf tolerance, is similar in other respects. Like California Common, it is susceptible to bacterial wilt. California Common 49 is recommended for those areas in California where dwarf disease is the major factor in reducing stands. Seed of this variety is in commercial production in such areas.

Other new varieties now on the market but still in preliminary stages of testing (1953) are Nomad, Sevelra, Rhizoma, and Du Puits. The first two of these were developed in this country, and the last two were introduced from Canada and France, respectively. Nomad has a relatively low forage-yielding capacity. It is being tested for pasture purposes in drier regions. Sevelra is a cold-resistant variety which shows some promise for hay and pasture in the Northwestern States. Rhizoma is susceptible to bacterial wilt, relatively winter hardy, and slow in growth recovery following cutting. Preliminary tests with this variety in the United States show no tendency of plants to creep as has been reported in some parts of Canada. Du Puits is relatively vigorous in growth, but it is susceptible to anthracnose, stem nematodes, and bacterial wilt.

Seed

Before buying alfalfa seed, the farmer should become familiar with the varieties best adapted to his locality. This information can be obtained from county agents or from State agricultural experiment stations. The surest way to get seed of an improved alfalfa variety is to buy certified seed. All the alfalfa seed-producing States certify

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seed as to variety, each package bearing a tag and seal to this effect. Varieties so certified include Grimm, Cossack, Ladak, Ranger, Buffalo, Atlantic, Narragansett, Vernal, Williamsburg, Indian, African, Chilean, Hardistan, Orestan, Caliverde, California Common 49, and Hairy Peruvian. Certified seed is grown under standards specifying eligible stock seeds and requirements for land, isolation, and purity necessary to maintain the true varietal identity and quality of the seed.

Certified seed of some new varieties adapted to the Northern, Central, and Eastern States is being produced in volume in the West. These varieties include Ranger, Buffalo, Atlantic, Narragansett, and Williamsburg. This rapid increase of new varieties was made possible through procedures adopted by the International Crop Improvement Association and State certifying agencies. These procedures permit production of certified seed both within and outside a variety's designated region of adaptation with assurance that genetic purity will be maintained.

When certified seed is produced outside of the designated region of adaptation, the following standards must be met: (1) Foundation or registered seed must be obtained as planting stock, (2) only the certified class of seed can be grown and is to be sold only for forage production, and (3) seed fields are limited to stands not exceeding 6 years of age. Field research tests, comparing certified seed produced in northern and central regions with seed of the same varieties produced in the Southwest, have not shown any significant differences in forage production when the above standards were met. Further studies are under way to determine the number of generations that seed of a particular variety can safely be grown outside its region of adaptation.

The stock seed supplies of certain of the improved varieties is being maintained by the National Foundation Seed Project. This will insure the necessary quantities of foundation, registered, and certified seed of each variety.

In buying noncertified alfalfa seed there are three points on which the purchaser should have information: (1) The name of the variety, (2) the section of the country in which it was produced, and (3) the quality of the seed with regard to purity and its ability to germinate. Unfortunately, it is not possible to distinguish between varieties or strains of alfalfa by the appearance of the seed, and at times owing to misrepresentation, intentional or otherwise, farmers have had difficulty in obtaining seed of the alfalfa desired.

State seed laws and the Federal Seed Act require that alfalfa seed be labeled to indicate origin. The farmer purchasing seed should observe the information given on such labels. Point of origin for domestic seed can often be determined from tags attached by the United States Verification Service, which verifies the origin or place where the seed was grown, without regard to the variety, quality, purity, or germination. Foreign origins can be detected readily by the presence of some seed artificially stained with a bright contrasting color. The Federal Seed Act requires that certain percentages of all lots of imported seed be stained before the seed is permitted to enter the United States, the color depending on the origin or adaptability of the seed as determined by tests conducted in this country. Staining regulations set forth in the Act are as follows: 1 percent of the seed

from Canada, which is well adapted to use in the United States, shall be stained violet; 10 percent of seed from South America shall be stained orange-red; 10 percent of other imported seed shall be stained red (1) if it is of unknown origin, (2) if it is of an origin other than Canada or South America, (3) if it is of mixed origin that would require more than one color stain, or (4) if the seed of foreign origin has been mixed with alfalfa seed grown in the United States.

The viability of the seed, or its ability to germinate, is ordinarily indicated in its appearance. Plump seeds of a bright olive-green color almost invariably germinate well, whereas shriveled seeds or seeds that are of a brownish color usually germinate poorly. Alfalfa seed turns reddish brown with age and, although some viable seed may possess this color, such seed should not be purchased without a germination test, even if it is offered at a price materially less than that asked for seed of a fresh olive-green color. When a germination test is desired it can be made by placing 100 seeds between cloths or blotting paper and keeping them moist and at a temperature of about 70° F. After 5 or 6 days most of the readily viable seeds will have sprouted. There will be some, however, that will remain hard, especially if they are of the variegated varieties. Many of these hard seeds will grow when put in the ground and, therefore, they should be considered in estimating the percentage of germination.

Every farmer should become familiar with the impurities and noxious weed seeds that alfalfa seed commonly contains, so that there may be no serious delay in buying the seed. Seed to be acceptable should not contain more than 2 percent of impurities. Each lot should be carefully examined for seed of noxious weeds before purchase. A report on purity and germination may be obtained by submitting a sample of seed to seed laboratories of State agricultural experiment stations or to commercial laboratories recommended by experiment stations.

Climatic and Soil Relations

The distribution of alfalfa in the world indicates a remarkable adaptability to a wide range of climatic and soil conditions. Although the crop requires considerable moisture to produce profitable yields of hay or pasturage, it does best in a relatively dry atmosphere where irrigation water is applied. Alfalfa grows well under warm, humid conditions, but forage yield and quality may be impaired by diseases which attack the crown, stems, and leaves of the alfalfa plant.

In the United States alfalfa succeeds at altitudes ranging from below sea level in the Imperial Valley, California, to 8,000 feet in the mountains of Colorado. It withstands hot weather well, but is seriously affected by the cold weather of winter and early spring. To what extent extremely low temperatures alone are responsible for the death of alfalfa plants during the winter is not known, but this, together with other winter conditions, commonly results in high mortality. On poorly drained clay soils, alternate freezing and thawing, such as occur in many sections, frequently do much damage to alfalfa by heaving the plants out of the soil and incidentally breaking the roots 6 or more inches from the crown.

Deep loams with open, porous subsoils are undoubtedly best for alfalfa, but where other conditions are favorable the plant has a very

wide range of adaptation insofar as soils are concerned. On account of the deep, penetrating character of its root system, alfalfa does not thrive on a soil that has impervious subsoil, hardpan, or bedrock near the surface. Instances have been observed, however, where it has made satisfactory growth on soils underlain at 18 inches by limestone ledges.

Good surface drainage and underdrainage are both necessary if alfalfa is to thrive. During the growing season complete submergence for 24 or 48 hours may do considerable injury, but when the plants are dormant they may remain under water several days with no serious damage. The formation of ice sheets on alfalfa fields during the winter months may cause severe injury. It is sometimes possible in such cases to reduce the amount of damage by breaking up the ice sheets with a disk or similar equipment. Alfalfa seldom succeeds if the water table comes close to the surface or if the level of the water table fluctuates considerably.

In the eastern part of the United States, rich river bottoms and soils of limestone origin are best suited to alfalfa, provided they are well drained. However, with suitable soil amendments the crop can be grown successfully on a wide variety of soils. On strongly saline and alkali soils, such as are frequently found in the West, alfalfa makes little or no growth.

Choosing a Field for Alfalfa

In selecting land for alfalfa careful consideration should be given to the texture of the soil, its productivity, and drainage. Where possible, very sandy or very compact soils should be avoided. The character of the subsoil requires special attention. It is a waste of time and money to attempt to grow alfalfa on land that is underlain at shallow depths by hardpan or other impervious layers. The character of the soil and subsoil can be determined through the use of the soil auger.

The most productive soils on the farm should be selected for alfalfa. Where good drainage does not exist naturally, it must be supplied by artificial means before alfalfa can be expected to succeed. Tile drains placed 3 feet below the surface will ordinarily lower the water table sufficiently to insure the satisfactory growth of alfalfa, other conditions being favorable. Drains may sometimes be clogged by alfalfa roots, but this occurs so seldom that it is of minor importance.

Preparation for Alfalfa

The Preceding Crop

Alfalfa may be grown successfully after almost any crop provided proper attention is given to the preparation of the soil following removal of the preceding crop. In deciding on the crop alfalfa is to follow, one should be chosen that fits well into the particular system of farming and at the same time leaves the land in good condition for alfalfa. Consideration also should be given to the time available for preparing the seedbed for alfalfa after the preceding crop has been harvested.

Young alfalfa plants are very tender and are likely to be killed by weeds during their early stages of growth. Therefore, it is best to

precede alfalfa for 1 or 2 years with some cultivated crop, such as corn or potatoes in the North, and corn, tobacco, or cotton in the South.

Except in the extreme North, small-grain stubble may usually be worked up in time for late summer sowing, provided the land has previously been treated to destroy weeds. The chief objection to such a practice is the possible lack of moisture in the soil, due to the demands of the grain crop and the hot weather of summer. Crops such as cowpeas and soybeans that smother weeds may be used advantageously in some areas to precede late-summer- or fall-sown alfalfa. In some areas, particularly in the Southeast, one of the recommended practices is to plant a legume cover crop, such as lespedeza (with small grains) or soybeans, in the spring and disk it in thoroughly 4 to 6 weeks before planting time.

Preparing the Seedbed

The tender nature of young alfalfa plants requires that the soil be in excellent tilth at sowing time. Many of the failures to obtain a good stand may be traced directly to a poorly prepared seedbed. Extra effort in proper preparation of the seedbed for alfalfa will pay dividends. Oftentimes a thorough job of plowing is done but the soil is left so loose that small seedlings cannot get established. An ideal seedbed may be obtained by using repeatedly, subsequent to plowing, tillage operations which will finely pulverize and compact both the subsurface and surface. This may be accomplished by plowing in the fall, disking several times in the spring, and harrowing occasionally to keep down the weeds until sowing time. Where fall plowing is not practicable, the land should be broken at least several weeks in advance of sowing. The soil should then be disked and harrowed at frequent intervals to settle the seedbed. The cultipacker may be of considerable assistance in getting the soil into the desired condition. To avoid puddling of the soil, the seedbed should never be tilled or worked when too wet.

In the Northeast, where alfalfa is sown the same season after the removal of a crop of small grain, it is generally better to avoid plowing except on the heavier soils, because there is seldom enough time for the soil to become properly settled before sowing. If such land is well prepared for the grain crop, a thorough disking followed by one or two harrowings will ordinarily leave the seedbed in fairly good condition. Land that has been in early potatoes, peas, or sweet corn can usually be prepared satisfactorily by removing the vines or cornstalks and harrowing. In preparing clover sod for alfalfa, the land should be plowed as soon as the crop is removed and should be disked and harrowed until a firm, fine seedbed is obtained. The preparation of sod land may be facilitated by cutting the sod with a disk before plowing.

In semiarid regions summer fallowing is often practiced to insure satisfactory moisture conditions for the seedlings the following spring. This method is also effective in any section for ridding the ground of weeds, but it involves considerable expense. Avoid any seedbed-preparation practices that might lead to soil blowing, especially in certain parts of the Great Plains.

Liming

Alfalfa stands out among legumes as a heavy consumer of lime. If there is any doubt about the need for lime, the question should be settled before time and money are wasted in an effort to get alfalfa started. Because the lime requirements of soils vary so widely, the prospective grower of alfalfa would do well to seek more exact advice on the probable need for lime from his county agent or State agricultural experiment station.

In the humid East, it is safe to assume that all soils except those of limestone origin will require lime for alfalfa. Even limestone soils are often acid at the surface, and lime must be applied before alfalfa will succeed on them. With the exception of the soils of the Pacific slope in northwestern United States, which have a high lime requirement, most of the nonsandy soils west of a line extending from central

Figure 3.—Specially equipped trucks are often used for spreading lime on land being prepared for alfalfa.

Texas to approximately the 96th meridian at the Canadian border do not require liming. All sandy soils, wherever they are located, should be checked for needs of lime before alfalfa is planted.

There are several different forms of lime on the market, such as burnt lime, slaked or hydrated lime, dolomitic limestone, ground limestone, sugar-mill and paper-mill waste lime, oystershells, chalk, and marls. More than 90 percent of all liming material used in the United States is ground limestone. The quantity of lime required depends on the soil, but ordinarily not less than 2 tons of ground limestone per acre or the equivalent in other forms of lime are needed. In many cases much larger quantities are required. One application usually lasts several years. Overliming should be avoided. For more complete information on liming practices, see Farmers' Bulletin 2032, Liming Soils for Better Farming.

When practicable it is well to apply part of the lime the season previous to sowing the alfalfa. This is particularly advisable where

ground limestone or oystershells are used, as the lime in this form is not so readily available as is the burnt lime. Where it is not convenient to apply any part of the lime the preceding season, it is preferable to apply it 3 or 4 weeks before the seed is to be sown, so that it may be thoroughly incorporated with the soil. If the land is not plowed, the lime should be thoroughly disked into the soil. In many sections of the country lime is spread on the land from the truck that delivers it from the dealer (fig. 3). Any method that spreads the lime evenly and at low cost is satisfactory. Topdressing an alfalfa stand with lime is not usually recommended.

Fertilizing

Alfalfa, being a heavy feeder, requires an abundance of available plant food in the soil for its best growth. On most soils east of the 95th meridian alfalfa responds to some sort of fertilizer treatment. The greatest need seems to be for phosphate and potash, and liberal applications will in most cases yield profitable returns.

Alfalfa requires some nitrogen in the soil for its early growth, but after it is once established, other conditions being favorable, it is able to get its supply from the air by means of the bacteria in the nodules on the roots.

Good barnyard manure furnishes not only organic matter, but also various plant-food elements required by alfalfa. For this reason it is a relatively satisfactory fertilizer material. Manure may be applied to the previous crop; it may be applied in the autumn and plowed under prior to sowing alfalfa; or it may be turned under in the spring where fall plowing cannot be done. Manure should always be applied long enough in advance of planting so that it will become well incorporated with the soil. Superphosphate is sometimes added to the manure. If manure is not available, the organic matter may be supplied by plowing under some green-manure crop. In the North such crops as rye, vetch, and Canada field peas may be used. Farther south burclover, crimson clover, soybeans, and lespedeza answer the purpose well.

Alfalfa has shown excellent response to commercial fertilizers in many areas of the country, but particularly in the Eastern States. In many of these States fertilizer is the key to successful alfalfa production. As much as 700 to 1,000 pounds per acre of a 2–12–12 fertilizer is recommended at seeding, with possibly smaller quantities in the midwestern and northern regions. Alfalfa that is adequately fertilized at seeding usually will not require topdressing the first year. Thereafter, however, it should be topdressed annually with phosphate and potash, the amount depending on the requirements of the particular soil. In many cases an annual application of 400 to 600 pounds per acre of 0–14–14, 0–10–20, 0–9–27, or the equivalent is required. Light applications of 20 to 35 pounds per acre of borax at time of seeding have been beneficial in many areas in the Eastern States. Annual topdressings of 15 to 20 pounds of borax in this region are recommended. Heavier applications may be injurious. In any case, the mineral supply should be kept up because 1 ton of alfalfa hay removes about 12 pounds of phosphoric acid and approximately 45 pounds of potash from the soil.

Other forms of fertilizer may be used to supply the elements needed by alfalfa. Potassium deficiencies may be corrected by periodic ap-

plications of muriate of potash. Generally speaking, raw rock phosphate has not given as satisfactory results as superphosphate, as it is much slower acting. Most experiments in the Eastern States indicate that alfalfa is not benefited by applications of flowers of sulfur.

West of the 97th meridian many of the soils do not require any special fertilizer treatment for alfalfa. There seem to be an increasing number of cases, however, where land that has given good yields of alfalfa for several years failed for some reason when reseeded. This often indicates a deficiency of certain plant-food elements. In such cases the use of superphosphate has often proved highly beneficial. On some of the lands of the Pacific Northwest, particularly in Oregon, applications of 50 to 100 pounds per acre of flowers of sulfur have given greatly increased yields. On the same soils gypsum has increased the yields of alfalfa. On certain soils in this region light applications of borax have resulted in greatly increased yields. In many cases, however, these fertilizers, if they produce any increase in the growth of alfalfa, do not give sufficient increase to justify the extra labor and money involved, and the farmer is advised to avoid any great expense in connection with their use until he has first determined on a small scale whether they will produce any appreciable benefit.

Flowers of sulfur is irritating to the eyes and nasal passages and will cause skin irritation if it comes in contact with perspiration on the skin, such as under the arms. Dusttight goggles with indirect ventilation and an approved respirator should be used. A full facepiece respirator can be obtained that protects both the eyes and respiratory organs. Suitable clothing should be worn to protect the parts of the body where perspiration collects.

Inoculation

Most of the soils in the Great Plains and Western States, with the exception of those in the Pacific Northwest coastal region, are naturally supplied with proper bacteria for inoculating alfalfa. In the eastern part of the country, however, where soil conditions are less favorable to the growth of nitrogen-fixing bacteria, it is nearly always advisable to inoculate at the time of sowing. Fields that within the past few years have grown alfalfa, sweetclover, burclover, or black medic successfully will not ordinarily need further inoculation for alfalfa, but the best advice is to inoculate.

To inoculate, use one of the artificial cultures put out by commercial firms. Instructions for use accompany these cultures. In recent years considerable progress has been made in selecting efficient inoculation cultures. Now that farmers can purchase legume inoculants prepared with the most effective strains, the simplest, easiest, and most economical way is to inoculate legume seed before each planting. Good advice is: Inoculate in all cases of doubt and always on new land. For further information on inoculation, see Farmers' Bulletin 2003, Legume Inoculation: What It Is, What It Does.

Another way of getting a new stand of alfalfa well inoculated is to scatter soil from a successful alfalfa field or from the roots of sweetclover or burclover plants. This method, however, is tedious and may scatter weed seeds.

Investigations indicate that the bacteria will live in the soil for many years, provided the soil is kept well supplied with organic

matter and lime, even though alfalfa or sweetclover is not grown on the land. If the soil is allowed to become strongly acid or to lose a large part of its vegetable matter the bacteria decrease very rapidly.

Sowing Alfalfa

Method of Sowing

The method of sowing varies considerably in different sections. Sowing may be done with a grain drill with a seeder attachment or with an alfalfa drill (fig. 4), or the seed may be broadcast with a hand seeder, a wheelbarrow seeder, or by hand and covered with a

Figure 4.—An alfalfa drill with cultipacker attached. Packing after drilling places the seed in close contact with the soil.

light harrow, a weeder, or a brush drag. To insure a more even stand, it is best to sow half the seed one way across the field and the other half at right angles to the first sowing. The depth to which the seed should be covered depends on the character and condition of the soil. On heavy soil one-half inch is usually sufficient, but on sandy or dry soils greater depth is usually necessary to insure getting the seed in contact with moisture.

The use of a cultipacker before sowing helps to make conditions favorable for germination. Good results have been obtained by first running the cultipacker over the land, then sowing the seed, and finally harrowing lightly or cultipacking again at right angles to the first cultivation.

Good results are occasionally reported from broadcasting on honeycombed ground during late winter or early spring. With abundant rainfall and ideal soil conditions, sowing alfalfa in corn at the last cultivation has sometimes given good stands, but it can hardly be

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called a safe practice. The presence of corn stubble may be more or less troublesome in the first cutting the next season unless the corn has been cut very close to the ground. Sowing in small-grain stubble is advised where soil blowing is troublesome.

Time of Sowing

In the northern half of the United States, where rainfall is abundant and soil conditions are suited to alfalfa, seed is often sown early in spring with a nurse crop. When sown alone, late-spring or early-summer sowing is generally best, as this gives an opportunity for preparing a good seedbed and at the same time permits the plants to become thoroughly established before cold weather. In the Southeast the most favorable time varies from the middle of August in the latitude of Washington, D. C., to late October or early November along the Gulf coast. February and March sowings are sometimes successful in the extreme South, but late-spring and early-summer sowings are likely to be crowded out by weeds.

In the northern part of the dry-farming area of the Great Plains it is almost necessary to sow seed as early in the spring as the land can be put into shape, as moisture conditions are most favorable at that time. During the summer the soil usually is so dry that the young plants are not able to make sufficient growth to withstand the cold winters. In the southern part of this area, however, good stands are often obtained from late-summer and early-fall sowings.

In the irrigated districts of the Southwest, October is the best month for sowing alfalfa, although good stands are obtained almost any time between October 1 and April 15. The hot summer months constitute the most unfavorable period. In the North spring sowings are most satisfactory, although good stands have been obtained when the seed was sown in grain stubble late in summer or early in fall.

Rate of Sowing

The quantity of seed necessary to insure a sufficient number of plants per acre varies in different parts of the country and depends directly on the condition of the seedbed. If every seed should grow, 1 or 2 pounds per acre would be ample, but some seeds are not viable, and others are covered too deeply or fall in dry soil and fail to germinate. Furthermore, many plants that start to grow die in the seedling stage, from one cause or another. For these reasons it is always advisable to sow a larger quantity of seed than would be necessary under ideal conditions. Most State experiment stations east of the Appalachian Mountains recommend 15 to 20 pounds of seed per acre, although several, particularly those in the Southeast, still recommend 20 to 30 pounds per acre.

In the Corn Belt seeding at the rate of 10 to 15 pounds per acre is advised by most State experiment stations, though 8 to 10 pounds have been shown to produce a satisfactory stand on well-prepared seedbeds. Under dry-land farming conditions in the Great Plains and Western States 6 to 8 pounds per acre is recommended for hay and one-half of this amount for seed production when drilled or sown broadcast. In rows, 1 to 3 pounds per acre is ample, depending on the moisture supply, the lower rate being better where moisture is limited. In irrigated districts most State experiment stations advise

using 12 to 20 pounds of seed per acre and occasionally more for hay or pasture, and about one-half this amount for drilled or broadcast seeding intended for seed production.

Alfalfa Mixtures

In the West where environmental conditions are naturally suited to the production of alfalfa, the crop is seldom sown in mixtures with grass, if it is intended for the production of hay or seed. Under such conditions mixtures usually produce little or no more than alfalfa alone. If the crop is to be used primarily for grazing, alfalfa is usually sown in mixture with some adapted grass. North of the Kansas-Oklahoma line bromegrass is most generally used for this purpose, although some crested wheatgrass and slender wheatgrass are used. In the Northwest, where alfalfa is grown under irrigation and at high altitudes, timothy or bromegrass, or both, are often sown with alfalfa, clover sometimes being added to the mixture. In the southern Great Plains alfalfa is usually sown alone. In the irrigated valleys of the Southwest, barley is frequently sown in the fall in established stands of alfalfa, such fields being grazed during the winter and early spring. In thin stands of alfalfa, Sudan grass is sometimes sown in the spring or early summer to increase the yields. In the Corn Belt it is a rather common practice to sow timothy or bromegrass with alfalfa, particularly on soils that are not well adapted to alfalfa. Under most conditions the Ohio Agricultural Experiment Station has found a mixture of timothy, clover, and alfalfa more productive and preferable to alfalfa alone. In the Northeast a similar mixture is being used to a considerable extent under less favorable conditions. In the Southeast alfalfa is usually sown alone.

Nurse Crops

If a nurse crop can be used without decreasing the stand of alfalfa, it is desirable, as it gives some return from the land while alfalfa is becoming established. The chief objections to a nurse crop are that it draws rather heavily on the moisture supply of the soil, and since it is harvested at a hot time of the year, the sudden change from the shade afforded by the nurse crop is likely to injure the alfalfa seedlings.

The practice of making early-spring seedings with any one of the small grains where conditions are favorable for alfalfa is becoming more general, and satisfactory stands usually result. The small grains are probably no harder on the alfalfa than the heavy growth of weeds that is generally produced in early seedings without a nurse crop. Any one of the spring grains, preferably an early maturing variety, may be used as a nurse crop. Such evidence as is available indicates that flax, in regions adapted to this crop, is one of the safest nurse crops for alfalfa. It is usually advisable to sow the grain in wider rows or at about one-half the normal rate and harvest it as soon as it shows evidence of injuring the alfalfa. Good results have also been reported from sowing alfalfa with winter wheat sown in the spring. In parts of the Northeast satisfactory stands are obtained when alfalfa is sown with canning peas, as they are harvested early and are less injurious to the young seedlings than small grains. Alfalfa is sometimes sown in the spring in winter wheat or rye, but the results from sowing in such established crops are less likely to be satisfactory. Wheat or

rye ground is often rather compact, and since alfalfa seed must be covered to insure a satisfactory stand it is necessary to loosen the soil before drilling or broadcasting alfalfa seed. In some cases it is advisable to follow with a harrow after seeding to insure better covering.

In the dry-farming regions, where moisture is the limiting factor, the use of a nurse crop will ordinarily result in failure of the alfalfa except in seasons of abundant rainfall. Under irrigation, however, alfalfa can generally be successfully grown with nurse crops. The practice is commonly advised in spring sowings in the northern irrigated districts, but farther south it is considered a better practice to sow the alfalfa alone. A nurse crop is seldom used with late-summer- or fall-sown alfalfa, except occasionally in the Southwest.

Growing Alfalfa in Rows

At one time it was believed that growing alfalfa in cultivated rows would be advantageous in regions of limited rainfall. It was hoped that in such regions it would be possible to produce satisfactory yields of hay and seed in this way. Farmers, as well as investigators of the United States Department of Agriculture and several State experiment stations, have given the method a thorough trial. The results of these tests indicate that where rainfall is not sufficient to produce profitable yields of hay in broadcast or close-drilled fields, it is likewise insufficient for alfalfa in cultivated rows. Where rainfall is very limited the yield from rows is somewhat greater than that from the close-drilled fields, but not large enough to justify the extra expense. Cultivation to keep down weeds adds considerably to the expense of growing the crop. Moreover, the hay is of a poorer quality, as it is dusty and contains many small clods of dirt.

With the limited moisture available under semiarid conditions, alfalfa in rows usually produces a higher average yield of seed than when drilled or sown broadcast. This method of producing seed is common under both irrigated and dry-land conditions in the West.

Instructions for Growing Alfalfa

In Michigan, Wisconsin, Minnesota, New York, and the New England States

In Michigan, Wisconsin, Minnesota, New York, and the New England States the following practices are observed in the growing of alfalfa.

Attention is given to the need for lime, fertilizer, and inoculation, as mentioned on pages 12 to 15. Land intended for alfalfa should be in some cultivated crop, such as corn or potatoes, for 1 or 2 years before sowing alfalfa. The ideal seedbed is obtained by plowing in the fall and completing preparation in the spring. On some soils that have been in a clean-cultivated crop the previous season, a good seedbed can be prepared by disking and harrowing in the spring without the necessity of fall plowing. Under favorable conditions, good stands of alfalfa are obtained from sowing in the spring with a small grain as a nurse crop. An early-maturing variety of grain is preferable and should be sown at the rate of about 1 bushel per acre. To conserve moisture it is sometimes advisable to cut the grain for hay just after it has headed. If the grain lodges it should be removed

early; otherwise it may smother the alfalfa. Canning peas make an excellent nurse crop, as they are harvested early.

Successful stands are also obtained from sowing the seed alone in June or early July, but when this is done no return is obtained from the land the first year. For this reason most farmers prefer to chance sowing later, after some such crop as early potatoes or an early truck vegetable has been removed, as the land requires little preparation for alfalfa provided the vegetable crop has been well cultivated. It is seldom safe to sow alfalfa after a crop of small grain has been removed as there is barely time for the alfalfa to become thoroughly established before cold weather, and the moisture supply may be limited owing to the demands of the preceding crop. Seedings made later than the middle of August are not dependable, as the alfalfa may not make sufficient growth to withstand the winter.

On land that is well adapted to alfalfa 10 to 12 pounds per acre of clean seed that germinates 90 percent is sufficient, although several New England States recommend 15 to 20 pounds.

In Ohio, Indiana, Illinois, Iowa, Missouri, Kentucky, Pennsylvania, Northern New Jersey, and West Virginia

On most of the soils in Ohio, Indiana, Illinois, Iowa, Missouri, Kentucky, Pennsylvania, northern New Jersey, and West Virginia, lime, inoculation, and fertilization are essential for the best growth of alfalfa. Discussions regarding these features will be found on pages 12 to 15.

Where the land is well suited to alfalfa the seed is commonly planted early in spring with a small grain sown at about one-half the normal rate, or occasionally in winter wheat or rye. Better stands are assured if the alfalfa is sown in the spring. If the nurse crop begins to injure the alfalfa seedlings, it should be cut for hay. Early canning peas have also been successfully used as a nurse crop. Good results are often obtained if the seed is sown after an early crop of sweet corn, potatoes, or truck vegetables. Such land requires little preparation for alfalfa, provided it has been well cultivated. Small-grain crops usually mature early enough for late-summer sowings of alfalfa, but there is likely to be a deficiency in the soil moisture at this time, owing to the demands of the previous crop. An early crop of red clover may also be taken off soon enough to get the land into shape for alfalfa the same year. Such land will require considerable preparation, as it needs to be plowed and thoroughly worked before alfalfa can be safely sown.

The quantity of seed required varies with the perfection of the seedbed, the character of the soil, and the condition of the weather at sowing time. Under favorable conditions about 8 to 10 pounds per acre has proved sufficient, although most of the experiment stations in these States recommend 10 to 15 pounds.

If the weather is favorable and the soil is in good condition and free from weeds, it makes little difference when the seed is sown, as long as there is sufficient time for the plants to become well established before winter. During midsummer, however, the weather is usually too hot and the soil too dry to insure successful germination and growth of seedlings. It is not advisable to sow much later than the first of September.

In the Southeastern and the Gulf Coast States

The soils in the Southeastern States and the Gulf coast region, with few exceptions, are not naturally well suited to the production of alfalfa, and careful attention must be given to preparing the land for the crop. Consideration should be given to liming, inoculation, and fertilizing, which are discussed on pages 12 to 15. Weeds are especially troublesome in this region, and for this reason alfalfa should be preceded for 1 or 2 years by crops that are cleanly cultivated or by a crop which chokes out weeds. Corn and cotton are good preparatory crops. Early truck and potato crops furnish excellent opportunities for destroying weeds and may generally be taken off the land in time for sowing alfalfa. These crops leave the land in such shape that plowing is not necessary.

A common practice is to sow winter grain after a crop of corn or cotton has been removed, and sow lespedeza in February or March. Soybeans or cowpeas are sometimes used instead of lespedeza, but they are seeded after the grain has been harvested and the land plowed. Four to six weeks before time to seed alfalfa the legume is cut up with a disk, taking care to have as much vegetation on the surface as possible to prevent the surface soil from baking. It is desirable to disk lightly just before seeding to smooth the land and kill the weeds that have come up since the first disking. This disking should be followed by use of a cultipacker or rolling to firm the seedbed. The above procedure affords an excellent opportunity to apply lime and fertilizers at the proper time. The lime can be applied just before the cover crop is disked into the soil, thus mixing it in the top 4 to 6 inches. The fertilizer can be drilled into the soil any time between the heavy disking and the priming of the seedbed. On sloping land the operations should be on the contour.

In this region alfalfa is generally sown without a nurse crop at the rate of 15 to 25 pounds per acre. In the Piedmont sections, on the Mississippi Delta, and on the prairie limestone soils of Alabama and Mississippi, good stands are obtained with 15 to 20 pounds, but on the Coastal Plains, where the soils are sandy and weeds troublesome, 25 pounds per acre is usually recommended.

In the northern part of this region sowings made about the middle of August have given the best results on an average. In the South Atlantic and Gulf States the date of sowing may be delayed with safety until the middle of October, and when weather conditions are especially favorable successful stands are sometimes obtained from sowings made as late as the first of November, although they are not recommended. Early spring sowings—that is, in March—are sometimes successful in the extreme South.

Under Semiarid Conditions

Alfalfa is grown extensively in parts of the West where rainfall is limited and where water is not available for irrigation. In this region soil-moisture conditions are usually most favorable in the spring, and in the North it has generally been considered the best practice to sow as early in the spring as the ground can be put in shape. However, recent experiments indicate that in some sections, at least, weeds are less troublesome if sowing is delayed until the 1st to the 15th of May. This gives opportunity to work up the seedbed two or three

times, thus destroying many of the weeds. If sowing is delayed until the weather is hot and dry, the plants may not become well enough established to survive the winter. From Kansas southward seed may be sown either in the spring or early fall. Moisture conditions usually are most favorable in the spring, but weeds are likely to prove more troublesome when seed is sown at this time. For this reason many growers prefer clean cultivation during the summer, sowing the seed late in summer or early in fall.

Preparation for alfalfa should begin somewhat in advance of sowing, to insure sufficient moisture for the young seedlings. If the seed is to be sown in the spring the land should be summer-fallowed the previous year or devoted to some cultivated crop, such as corn, to assist in freeing it of weeds and to conserve moisture. Except on heavy soils it will not be necessary to plow again, but where plowing seems advisable it should be done in the fall and the land disked and harrowed as soon as it is in condition to be worked the following spring.

Land to be sown late in summer or early fall should be plowed the previous fall and kept cultivated throughout the spring and early summer.

A nurse crop with alfalfa is not recommended under dry-land conditions, as it draws too heavily on the limited moisture supply. Good stands, however, are frequently obtained with one-third or one-half the normal rate of sowing of some small-grain crop, provided it is cut early for hay. Good results are also obtained from the use of flax as a nurse crop.

Over most of the dry-farming area less seed is required than is advised under humid conditions or under irrigation, partly owing to the fact that weeds are less troublesome. Ordinarily, from 6 to 8 pounds of seed per acre is ample. Good stands have been obtained with 2 to 4 pounds, but such light rates cannot be recommended for general practice.

On Sandy Soils

In the Eastern States alfalfa usually does not survive long on very sandy soils, although fairly good yields may be obtained for 2 or 3 years where liberal applications of stable manure, plus fertilizers, are made prior to sowing. West of the Mississippi River such soils, if not too sandy, usually will grow alfalfa successfully after the plants are once well established. It is often difficult, however, to start the crop on soils that are so light in texture that they drift badly, as the young plants are likely to be cut off by blowing sand unless special precautions are taken. Drifting may be prevented by applying a light top-dressing of straw or coarse manure just after sowing. Another method is to scatter a thin layer of wild hay or straw from an old stack bottom over the land immediately after the seed has been sown. The field is then gone over with a weighted disk set straight. This cuts the hay into the ground and leaves it standing over the field, much like stubble. Good results are also produced if the alfalfa is drilled into high-cut stubble of small grain, sorghum, or millet. Where cornland is used and the field is in good shape, it may be prepared by disking down the stalks early in the spring and leaving the soil rough until time for sowing. Alfalfa seed may also be sown with about 1 peck per acre of rye, barley, or some other small-grain crop

that will make rapid growth and protect the alfalfa seedlings. Unless there is danger of injury from drifting soil the nurse crop should be avoided, as it is likely to draw so heavily on the soil moisture as to injure the alfalfa.

The rate of sowing generally advised is from 10 to 15 pounds per acre. The press drill gives the best results, but if it is not available, the seed may be sown broadcast and the land harrowed and then rolled to get the seed into contact with the moist soil and hasten germination.

Under Irrigation

In preparing irrigated land for alfalfa the first step is to break the soil deeply and then level it if necessary. Plowing should be done several weeks in advance of sowing so that the soil may be properly compacted by the use of a heavily loaded disk, a roller, or some other suitable implement. Ordinarily it is best to irrigate the land just before sowing; and, as soon as it has dried out sufficiently, the surface should be worked up into a fine mellow seedbed. If possible, further irrigation should be avoided until the plants have developed three or four leaves. Good stands are sometimes obtained where the seed is "irrigated up," but the practice is not recommended, particularly on heavy soils, as the surface often becomes so crusted that the young plants are unable to break through.

For ordinary conditions the rate of sowing should be about 15 pounds per acre, although a smaller quantity may give good stands under ideal conditions. Generally speaking, somewhat less seed seems to be required in the northern irrigated districts than farther south, probably because weeds are less troublesome. The time of sowing depends upon frost conditions, but should be early enough to allow the plants to become well established before cold weather. In the extreme Northern States the best stands are obtained where the seed is sown as early in the spring as it is possible to get the land in condition. Ordinarily, at this time of year the soil contains considerable moisture as a result of winter precipitation, and irrigation prior to sowing is not essential. Another advantage of early-spring sowing is that during cool weather the soil does not dry out very rapidly and the plants have an opportunity to become well established before irrigation is necessary. In Montana and the Dakotas the latter part of April or early May is about the earliest date that alfalfa can be sown safely. Under favorable conditions in these States good stands have been obtained where seed was sown on disked grain stubble late in summer. In the extreme Southwest good stands may be obtained from sowing between October 1 and April 15, although the December and January sowings are occasionally injured by cold weather. October is the most favorable month, but where it is impossible to get the land in shape in the fall, February and March sowings usually give satisfactory results. The hot summer months constitute the most trying period.

As a rule, the best stands are obtained where alfalfa is sown alone. In the Northern States, however, a nurse crop is not particularly objectionable, provided it is sown at about one-half or one-third the usual rate. In the Southwest a nurse crop is not recommended.

Treatment of Stands

Late-summer or fall-sown alfalfa requires no treatment that season. Even though the plants make considerable growth before being checked by frost, they should not be cut. Where alfalfa is sown in the spring, weeds usually appear in abundance, and the important question is whether it is better for the alfalfa if the weeds are cut back or allowed to grow. A generally prevailing theory is that frequent cutting of young plants forces them to stool out and increases root growth, but carefully controlled experiments have demonstrated quite clearly that such treatment actually checks root development. Even where weeds are rank, it is better to delay clipping until the young alfalfa plants are in bloom. Although the earlier clipping may check the weed growth to some extent, it also weakens the alfalfa seedlings and lessens their ability to compete with the weeds.

When the field is cut, the growth should be removed if there is any danger of smothering the seedlings; otherwise it may be left on the ground as a mulch. In the northern Great Plains and the intermountain region, weeds in alfalfa have been allowed to go unclipped throughout the first season, the subsequent stand of alfalfa benefiting by such treatment. Where this is done it is advisable to get rid of the dead growth early in the spring. In the North, where only hardy alfalfas are grown, this has been accomplished by burning over the fields, but the more tender alfalfas are sometimes injured by this treatment. Where it is not safe or convenient to burn off the fields the dead growth may be raked up and hauled off. In the South and Southwest it is often possible to procure two or three cuttings of hay the first year from spring sowings, and where this is the case the recommendations made above do not apply.

Alfalfa should not be pastured until after the first year, and should never be pastured closely, as the grazing down of the crowns often results in killing the plants. Rotation grazing is recommended to maintain stands and for high production. Cattle should never be allowed on a field when the ground is wet or frozen. Where the alfalfa is sown in the spring with a small-grain companion crop, grazing for a few days in a dry season reduces the growth of the companion crop and usually results in better stands of alfalfa.

Attempts to improve poor stands by overseeding generally fail. It is better to plow up unsatisfactory stands, plant the land to some cultivated crop for a year or two, and then reseed. In some areas it is possible, however, to seed timothy in thin stands of alfalfa and thus prolong the usefulness of the meadow. After the last cutting of alfalfa has been removed, the seedbed should be prepared with an alfalfa harrow or similar implement, and the timothy seed sown broadcast or drilled. Where adapted, orchardgrass may be used instead of timothy.

In the East a topdressing of well-rotted stable manure applied late in fall or in winter not only furnishes some protection but in most cases also increases the yield the following season. In addition, an application of 400 to 500 pounds of 0–14–14 fertilizer per acre in the spring will help to maintain the vigor of the stand. Potash is becoming increasingly important in growing alfalfa successfully in many eastern areas.

Cultivating Alfalfa

For many years the disking or harrowing of alfalfa fields has been advocated on the theory that it increases the yield and prolongs the life of the stand. Although some form of cultivation appears advisable under certain special conditions, any general statement to the effect that alfalfa fields are always benefited by such treatment is not borne out by actual experience. Where irrigation water leaves thick deposits of silt on the field, where the soil in irrigated fields has been compacted by cattle grazing on the alfalfa, or where attempts are to be made to improve the productivity by fertilizing or by sowing grass in thin stands, some sort of cultivation may be essential. There is little or no advantage, however, in cultivating broadcast alfalfa as long as the stand is satisfactory and the plants are making good

Figure 5.—Type of harrow commonly used in cultivating broadcast alfalfa.

growth. Extensive experiments have shown that under such conditions the increase in yields, if any, is not sufficient to pay the additional cost of producing the crop.

In seed-producing areas, however, alfalfa is often cultivated rather severely in order to destroy the weeds and thin the stands of alfalfa, as thin stands usually produce better yields of seed.

The best implement for cultivating alfalfa is the alfalfa harrow, which is a modified form of the spring-tooth harrow (fig. 5). When properly used, this implement loosens the soil without seriously injuring the plants. The spike-tooth harrow will loosen the lighter textured soils, but is of little benefit on the heavy soils. In most cases the use of the disk harrow is actually injurious, as any implement that has a tendency to split the crowns renders the plant more susceptible to certain diseases.

The best time for cultivating a field of alfalfa will depend upon the object to be gained. Ordinarily it should be early in spring or immediately after any one of the cuttings. Alfalfa should never be

cultivated the first year after sowing as the plants are so small that they are easily pulled out and killed.

Harvesting and Meadow Management

Most of the alfalfa grown in this country is cut for hay but in a few isolated areas relatively large acreages of this crop are harvested for dehydration and production of alfalfa meal. The number of cuttings obtained annually depends upon climatic conditions, the soil, cutting practices, and the variety of alfalfa and varies from two and sometimes only one in the North and semiarid sections to eight or more in the irrigated areas of the far Southwest. From 30 to 40 days are required to produce a hay crop.

The stage of growth at which alfalfa is cut has a marked effect on the yield, the feeding value of the forage, and life of the stand. Highest yields usually are obtained when growth is permitted to reach the full-bloom stage of development before cutting, but this lowers the nutritive value of the forage. Hay of the highest feeding value results from early cutting, owing to the greater proportion of leaves, which contain twice as much protein as the stems. Carotene, or vitamin A, an important constituent in alfalfa meal, is also at a high level in forage that is cut before it reaches the blossoming stage. Continued cutting as early as the bud stage, however, shortens the life of a stand under most conditions. In general, stands survive in best condition, and acre yields of protein tend to be highest when harvesting is delayed until the plants are at stages between one-fourth and one-half of full bloom.

The time and frequency of cutting alfalfa may materially affect the storage of plant-food reserves in the roots and subsequent performance of the alfalfa. Repeated experiments concerned with the physiological principles underlying these relationships show that rate and amount of top growth on established alfalfa plants, both early in spring and after each cutting of hay during the growing season, are closely associated with the amount of reserve food materials stored within the roots and crown. Most of the food materials needed in early growth and structural development of stems and leaves are drawn from the reserves contained within the underground portions of the plant. Along with the progressive development of new vegetation there is a rapid and continued lowering of food reserves in the roots for approximately 3 to 4 weeks (the time varies with environment and geographic location). Thereafter, the growing plants manufacture more food material than needed for their continued development. The replenishment of food reserves within the roots starts when the growth approaches the "bud stage" and continues at a very rapid rate until new shoots appear at the crown, or the plant reaches the $\frac{1}{10}$- to $\frac{1}{2}$-bloom stage of development. Additional amounts stored after the plant has attained this stage of maturity are usually so small that little or no advantage results from further delay of harvest.

Although harvesting at prebloom stages results in hay that is more leafy and higher in protein, this early removal of top growth usually gives lower acre yields of protein and definitely limits the amount of food re-stored in the roots. Repeated and continuous cutting at such early or premature stages results in a gradual lowering of the

reserves during the season and from year to year. Coincident with this, there is a weakening and loss of plants and consequent lowering of hay yields.

The most critical periods of growth as related to maintenance of a highly productive vigorous stand are late fall and early spring. It is important that fall growth be sufficient to permit the manufacture and storage of large quantities of food in the crown and roots if winter losses in stands are to be minimized. This may be accomplished by taking the last hay cutting of the season approximately 30 days or more before top growth of the plants is killed by frost. In the northern areas where alfalfa remains dormant throughout the winter season, healthy plants of winter-hardy varieties which have ample food reserves at the start of winter usually emerge in spring strong and vigorous. However, in regions where the winters are characterized by intermittent freeze-free periods of 2 to 3 weeks duration, alfalfa may start growth several times during the winter and as a result draw heavily on food reserves. Under such conditions, alfalfa which shows high levels of food reserves in the roots in early winter may start spring development in a relatively weak condition. In order that plants thus weakened may recuperate and continue to produce vigorous growth and high yields it is especially important that harvest of the first cutting be delayed until between the ¼- and ½- bloom stage.

When plants emerge strong and vigorous in spring, the first and possibly the second growth of the season may be cut at the late-bud or early-bloom stage without shortening the life of the stand, provided one or more of the later cuttings of the year are delayed until full bloom. By following this practice a better quality of hay is obtained from early harvests, which generally produce rank and coarse plant growth.

Although presence of flowers on alfalfa is commonly used to determine when the crop is ready to cut, this criterion sometimes has questionable value, particularly in the East where during wet or dry seasons, alfalfa frequently blooms sparingly. In such cases a suitable guide for the experienced grower to determine time for harvest is the color of the field. When growth begins to take on a yellowish cast other than that resulting from insect damage and the general appearance indicates that vegetative development is slowing down or stopping entirely, the alfalfa should be cut. Young shoots developing from the crown also indicate that the alfalfa should be cut.

More detailed information on alfalfa for hay and dehydration, and for other uses including pasturage and silage, and actual feeding of hay may be found in Farmers' Bulletin 1839, The Uses of Alfalfa.

Seed Production [3]

Alfalfa seed production is most dependable where the climate is relatively dry, as in the arid and semiarid districts of the West. The highest yields regularly occur in areas where the period from May to September is hot and dry. In some years much seed is obtained in the Middle West, particularly in northern Wisconsin, Minnesota, and Michigan, but the production in this part of the United States is rather

[3] The Section of Bee Culture, Entomology Research Branch, gave helpful suggestions in the preparation of this section.

erratic, being considerable in abnormally dry seasons, and relatively unimportant in wet seasons that favor rank vegetative growth. Arkansas, Louisiana, and States east of the Ohio and lower Mississippi Rivers generally have climatic conditions unsuitable for dependable and profitable seed production. Hence, farmers in this area regularly depend on seed for their planting needs for forage from the Great Plains and Western States.

As hot, dry weather favors seed setting, it is customary to save for seed the growth that matures during the hottest and driest part of the summer. Over much of the country this is the second crop, but south of Kansas it may be the third crop. In the extreme North, at high elevations where the season is usually short, and under dryland conditions where late-summer plant growth is limited by lack of soil moisture it is necessary to leave the first growth for seed. For a short time in the spring some growers pasture fields that are to be devoted to seed production. In the Southwest where seed production is the main crop, the stands are usually clipped only once. Here the long, hot, dry period is particularly important, first in facilitating bee activity for pollination, and later in carrying out successfully all harvesting operations.

Normally alfalfa flowers must be "tripped" by pollinating insects to set seed (fig. 6). The flower is tripped when an insect gathers pollen. Occasional blossoms may be tripped by insects working the flowers for nectar, but where populations of these insects are limited, such tripping is relatively ineffective in seed production. Pollinating in-

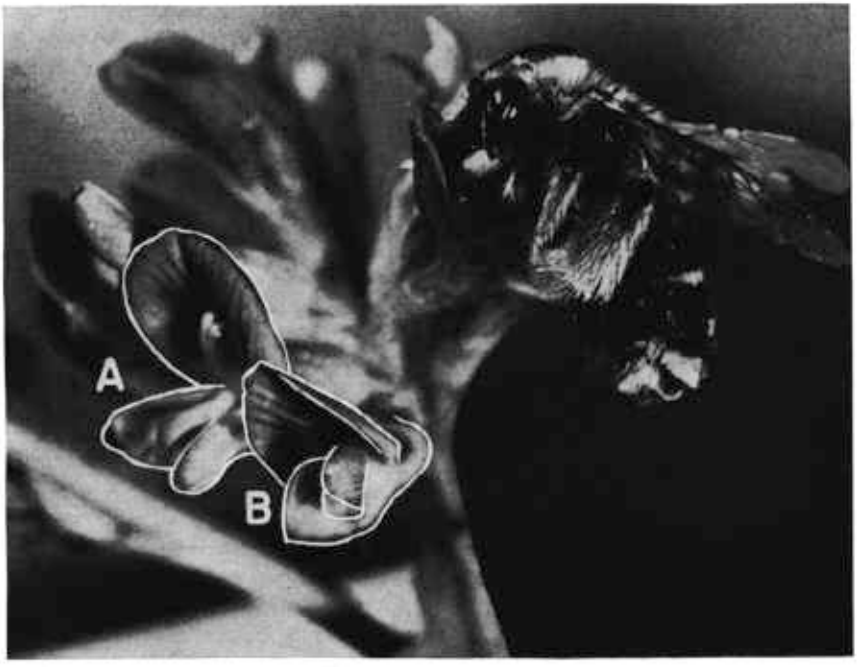

Figure 6.—*A*, an alfalfa flower tripped by the wild bee (*Melissodes* sp.) shown working another flower at right. *B*, an untripped flower. Flowers must be tripped to set seed. Cross-pollination occurs when the foreign pollen carried by bees is brought into contact with the exposed stigma.

sects include the solitary or ground bees such as the *Nomia* and *Megachile* species and bumblebees, honeybees, and others. Honeybees prefer many plants over alfalfa as a source of pollen. Therefore, if other flowering plants are present in the vicinity, alfalfa often is not effectively pollinated, and a poor seed crop results. In addition, if weather conditions are unfavorable for beneficial insect activity, or if pollinating insects are absent when alfalfa is in bloom, seed-crop failures result. Harmful insects may also cause seed-crop failures—this is notably true of the lygus bugs that are found in most seed areas of the country, and of the alfalfa plant bug, grasshoppers, the potato leafhopper, and others. Recent results with DDT and other insecticides show that these insects can be effectively controlled. A discussion of their control is given in the section, Control of Harmful Insects.

As a result of intensive studies during the past few years by the United States Department of Agriculture, cooperating with State agricultural experiment stations, it is now possible to give a rather clear picture of the essentials for successful alfalfa seed production.

First of all, it is necessary to have relatively normal plant growth, which means adequate consideration of soil fertility, including minor elements, and culture of the crop. In general, relatively thin plantings with a normal, steady, almost vigorous growth of the plant without sufficient stimulus to start much new growth from the crown appears to give the highest and most dependable seed production. Such conditions can be attained best under irrigation, but are also found under natural rainfall conditions. "Droughty" growth, such as might be obtained under semiarid conditions, is very good for seed production, but the total production per acre is usually small because of the limited growth. Often under semiarid conditions the crop is planted in rows to make more moisture available per plant. The crop should come into bloom during a period of dry, sunny weather, to insure maximum pollinating-insect activity and also for the proper response of the plant.

Three of the most important requirements in obtaining a successful seed crop are proper meadow management, control of harmful insects, and an abundance of pollinating insects during the blooming period. Failure on any one of these, regardless of how well the others may be handled, might result in low seed production.

Proper meadow management comprises the use of cutting practices which will maintain the alfalfa in a strong, vigorous condition. This is important especially in areas where alfalfa is cut intermittently for forage and seed. When used for such dual purposes, maximum seed yields are obtained by delaying harvest of the immediately preceding cut for hay until the growth reaches a stage between one-half bloom and full bloom. This allows the plants to accumulate in their roots the food reserves necessary for normal growth, production of an abundance of flowers, and nourishment of the developing seeds.

The control of harmful insects appears to be considerably simplified through the use of new insecticides now available. Control of these should be accomplished in a manner so as not to destroy pollinating insects needlessly.

Supplying an abundance of pollinating insects is still a difficult problem. In areas where competitive pollen plants are not a serious factor, honeybees gather pollen from alfalfa, and by so doing readily

trip the flowers. Under such conditions, the placing of honeybee colonies in or near the seed-producing field definitely increases seed production. Even in areas where there are competing plants, evidence indicates that concentration of honeybees in an alfalfa field may be beneficial. From 2 to 4 colonies per acre during the height of bloom are not too many. Under certain conditions, 6 to 10 colonies per acre have been used with profit to the seed grower. Honeybees may prove more effective if steps are taken to eliminate, as much as possible, competing pollen plants, such as roadside weeds.

With respect to wild bees, it is desirable to protect their homes to the fullest extent. Many nest in the ground, and these nests should not be plowed up. This is particularly true of the *Nomia*, or alkali, bee found in most Western States. Care must also be taken not to kill wild bees with insecticides used to control harmful insects. It may be possible at some future date to suggest ways of propagating these very effective wild-bee pollinators, but so far sufficient research has not been done to supply that information.

For a seed crop, alfalfa should be cut when two-thirds to three-fourths of the pods have turned brown or black. Many harvesting methods now being used are wasteful of seed; mowing followed by raking is an example. It is better to use a windrower attachment or a binder without the tying attachment in order to roll the alfalfa to one side, where it will not be crushed by the machinery. One of the most common methods is to use a windrower attachment on the mower, allow the hay to cure in the windrow, and then thresh with a pickup combine. All windrowing operations should be carried out at a time of day when the plants are damp and tough in order to minimize losses from seed shattering and breaking off of pods. This can best be done at late night in the drier sections of the country, or in early morning in areas where heavy dews are common. In a few isolated areas the seed crop is cut with a grain binder and tied in bundles or mowed and placed in small cocks for curing. When handled in this way, the ordinary grain thresher equipped with alfalfa sieves and with the concaves set close can be used satisfactorily in threshing. The combine can also be used as a stationary thresher. An alfalfa huller is still one of the best threshers, but very few are now available. In areas where strong winds, rain, and low humidity are a hazard to alfalfa seed production, preharvest spraying to cure the crop chemically for direct combining has been quite successful. This practice is becoming increasingly popular in many areas. A less satisfactory method, but possible under the most favorable ripening conditions, is to combine the standing crop without any preharvest treatment to top-kill the plants. When this method is used it may be necessary to spread the freshly threshed seed in a thin layer on a concrete floor or other suitable location and stir it frequently until dry to avoid heat damage.

In the Southwest, the acreage for seed is expanding rapidly. Yields from 400 to 1,000 pounds of seed per acre (about 6 to 16 bushels) are common. The use of honeybee colonies there is almost universal. They are usually placed along driveways through the field. Bee populations required for pollinating vary considerably depending on local conditions. In the southern San Joaquin Valley of California, the use of 2 to 3 colonies per acre produces more seed than the use of 4 to 6 colonies in the Sacramento Valley. No preferred pollen sources exist in the former area. Even the large acreage of cotton with its

abundant supply of pollen is visited only meagerly by honeybees for pollen. Pollen collected in pollen traps at the entrance of hives showed less than 5 percent of cotton pollen, and over 74 percent of alfalfa. In the lower Sacramento Valley, many good pollen sources, including yellow star-thistle, Ladino clover, morning-glory, and spikeweed, attract the pollen-collecting bees from alfalfa. Trapped samples from colonies of bees in alfalfa fields in this area usually contain no alfalfa pollen. Here the nectar-collecting bees are the chief pollinators, and since they are less efficient in tripping the flowers than the pollen-collectors, more bees must be used for best results.

The average yield of seed varies considerably from year to year, but in general ranges from slightly more than 1 bushel per acre for States in the Great Plains region to approximately 5 bushels per acre for several of the Western States. Longtime records for many localized areas show that as acreage and total production of seed increased, there was generally a decline in yield per acre. This probably resulted from failure of a corresponding increase in population of wild bee pollinators, and also from increased numbers of harmful insects. These limitations can now be overcome to a certain extent by the alert grower who takes advantage of present-day knowledge concerning the over-all problem of seed production.

Total seed production for the United States has increased steadily over the years. In the early 1930's, annual production amounted to approximately 50,000,000 pounds. During the following 20-year period this was more than doubled. An annual production of about 180,000,000 pounds was reached in 1952.

The importations of alfalfa seed have shown wide variation, ranging from 1,522,700 pounds in 1941, to 20,267,200 in 1949. Since 1949, there has been a slight decline in amount of seed brought in from other countries. Most of the imports in recent years have been from Argentina and Canada.

Breaking Alfalfa Sod

Farmers often complain of the difficulty of breaking up and destroying a stand of alfalfa, but under most conditions this need not be a problem. The plow should be in good condition when it enters the field, and the operator should keep it sharp. It is, of course, more difficult to keep the plow in condition in gravelly or stony soil.

The furrow slice should be 2 inches less in width than the plow will turn. This is to prevent any of the large roots from slipping by uncut. Sometimes the plows are provided with a knife attachment to the landside to cut the roots near the outer edge of the next furrow. The most successful practice is to plow shallow in the fall and deep the following spring. If only one plowing is practicable, this should be rather shallow. If plowed too deeply the roots frequently retain enough life to start again. Ordinarily it is better to leave the furrow slice to dry out some time before cultivating, as this assists in killing the roots.

Weed Control [4]

In most of the United States, weeds constitute one of the most serious problems in alfalfa production. Troublesome weeds in the

[4] Contribution from the Section of Weed Investigations, Field Crops Research Branch.

Northeastern States include bluegrass, quackgrass, and chickweed. In the southeastern and southern regions, crabgrass, foxtail grasses, Johnson grass, Bermuda-grass, cheatgrass, annual ryegrass, chickweed, knotweed, curled dock, pigweed, and lambsquarters are important pests. Some of the most serious weeds in alfalfa in the North Central region are the foxtail grasses, cheatgrass, chickweed, quackgrass, field peppergrass, and such perennials as Canada-thistle and plaintain. In the irrigated sections of the West and in the Pacific Coast States the wild barleys, foxtail grasses, pigweed, lambsquarters, shepherds-purse, and yellow star-thistle are troublesome.

Dodder, a threadlike yellow twining plant living as a parasite on plants, is very objectionable in seed-producing areas, as there is little or no market for alfalfa seed containing dodder, and the two seeds are very difficult to separate. Dodder seldom gives much trouble in fields that are devoted entirely to the production of hay.

Cultural Methods

The most satisfactory way to control weeds is to follow practices that will insure the establishment and maintenance of vigorous stands of alfalfa. Chemical or mechanical methods of weed control are not satisfactory substitutes for good cultural practices.

The use of clean, high-quality seed of an adapted variety of known pedigree and origin is a sound starting point for a good weed-control program in alfalfa production. Thorough seedbed preparation, followed by timely, efficient mowing and removal of hay or seed crops is extremely important. In the alfalfa-producing regions of the United States where bacterial wilt is prevalent, weed infestations become progressively more severe each year after the first hay year due to reduced stands when non-wilt-resistant varieties are used. On wilt-infested soils, resistant varieties should be used if stands are to be maintained for more than 2 or 3 years.

Where weeds are troublesome in the West, wheat is sometimes drilled in the alfalfa in the fall, and as it comes on early, the growth of the weeds is checked. The first cutting of hay the following spring consists of a mixture of alfalfa and wheat. Cultivation of established stands of alfalfa may help to hold the weeds in check, but unless done with considerable care the alfalfa may be injured. A more detailed discussion on cultivating alfalfa may be found on page 24.

Chemical Methods

Even though sound cultural practices are followed, certain weeds may still become serious pests. Winter-annual weeds may cause trouble in the dormant season when alfalfa affords little or no competition. Under certain conditions, fast-growing summer annuals may germinate before the alfalfa starts growth in the spring and seriously compete with the first crop, reducing the yield and resulting in weedy hay. Rapid-growing weeds may also become established after mowing when the alfalfa offers little competition. The control of weeds in seedling alfalfa is also very important to establishing and maintaining stands of alfalfa.

Herbicides can be used successfully and economically to supplement good cultural practices in the control of weeds in seedling and established dormant alfalfa. Several methods of application are being

investigated. These include preplanting, preemergence, and postemergence treatments. At present only the postemergence treatments with chemicals are being recommended for alfalfa, although applications during the other periods have also shown promise.

In seedling alfalfa, summer-annual weeds such as pigweed, lambsquarters, morning-glory, foxtail grasses, crabgrass, and ragweed, and winter annuals such as chickweed, henbit, and bachelors-button may be controlled by the ammonium, triethanolamine, or alkanolamine salts of 4,6-dinitro-ortho-secondary butylphenol (DNOSBP), 4,6-dinitro-ortho-secondary amylphenol (DNOSAP), and other dinitro derivatives. The dinitro compounds, when applied at ½ to 2 pounds DNOSBP equivalent in 20 to 100 gallons of water to alfalfa 4 to 6 inches tall, have given excellent control of broadleaved annual weeds with little or no injury to alfalfa (fig. 7). If grasses are serious,

Figure 7.—Herbicides can be used successfully in controlling weeds in alfalfa. Foreground, test plot on which weeds were controlled with 2 pounds of the triethanolamine salt of DNOSBP in 20 gallons of water applied when the alfalfa was 5 inches tall. Background, untreated area showing growth of bachelors-button and other weeds. (Courtesy of the North Carolina Agricultural Experiment Station.)

the oil-soluble dinitro compounds should be used. These chemicals at ½ to 2 pounds DNOSBP equivalent are dissolved in 20 to 40 gallons of oil, emulsified with 60 to 80 gallons of water, and applied at 80 to 120 gallons of mixture per acre. For the control of winter- and summer-annual weeds in established alfalfa, the higher rates of DNOSBP in the range of rates suggested above for seedling alfalfa should be used.

In alfalfa seed-production fields, and under other conditions where pure stands of alfalfa are desired, weedy annual grasses and cultivated grasses may become serious pests. For the control of grasses in seedling and established alfalfa, isopropyl N-(3-chlorophenyl)-carbamate (CIPC) at the rate of 1 to 4 pounds in 20 to 40 gallons of water per acre may be used. This chemical should not be used if grasses are desired in mixture with alfalfa.

A number of other herbicides such as 2,4-dichlorophenoxyacetic acid (2,4-D), 2-methyl-4-chlorophenoxyacetic acid (MCP), isopropyl N-phenylcarbamate (IPC), sodium trichloroacetate (TCA), and 3-(p-chlorophenyl)-1,1-dimethylurea (CMU) are being evaluated for weed control in alfalfa. Some of these herbicides appear very promising under certain conditions. They should not be used, however, unless recommended locally. To obtain the most recent information regarding their use, the farmer should consult his county agent, or his State agricultural experiment station.

Diseases

Alfalfa is susceptible to more than 75 diseases caused by fungi, bacteria, viruses, and nematodes. Many of these occur sporadically and are rarely destructive; several, however, are important in the major alfalfa-growing areas and are responsible for appreciable losses.

Figure 8.—Broadcast strip plantings of alfalfa: Center strip contains a variety susceptible to bacterial wilt; strips on either side are wilt resistant.

One of the most important diseases attacking alfalfa is bacterial wilt. Wilt is one of the major factors causing depletion of stand and reduction in longevity of alfalfa (fig. 8). Fortunately, resistant varieties such as Ranger, Buffalo, and Caliverde are available for the northern, central, and southwestern (principally California) alfalfa-growing regions, respectively. Seed of the wilt-resistant variety Vernal soon will be available in Wisconsin and other northern areas where this variety may prove adapted.

Root and crown rots occur in all regions where alfalfa is grown. The fungi causing these diseases are among the most destructive pathogens. They can cause injury at all stages from seedling to ma-

ture plant. Some are most active during cool, moist periods of winter or early spring, whereas others are strictly warm-temperature fungi. Crown rot fungi differ from the root-rot group in that they attack primarily the older plants and are probably the major cause of so-called "winterkilling," and also summer losses, which commonly occur in the humid East, Southeast, and Pacific Northwest. Both of these groups of rot diseases are among the most difficult diseases of alfalfa to control.

Many disease organisms affect the foliage of alfalfa. Certain diseases such as anthracnose and blackstem attack the stems, but sometimes spread into the crown and upper part of the taproot, severely weakening or killing the plant. Anthracnose is favored by warm, humid weather and occurs principally in the Southern and Eastern States. Most alfalfa varieties tolerate the disease except when conditions are very favorable for its development. The variety Du Puits is very susceptible to anthracnose. Blackstem occurs throughout most of the alfalfa-growing areas, but is most serious in the cooler, humid regions. The name "blackstem" is misleading since the disease can attack any part of the plant from root to seed. Since the fungus overwinters on old cut stems and old growth from the previous season, sanitation is important for reducing losses.

Several other leaf diseases are widespread and sometimes damaging to alfalfa. Common leaf spot and yellow leaf blotch may occur so abundantly that they cause serious loss of leaves. Most varieties of alfalfa contain some resistant plants and desirable lines are being developed at several experiment stations.

The less important, but occasionally locally prevalent foliar diseases include downy mildew, summer blackstem, leaf rust, and *Pleospora* leaf spot.

Two virus diseases of importance mainly in the Western States are "dwarf" and "witches broom." Alfalfa dwarf is known to occur only in California, and is an important factor in thinning 2- and 3-year-old stands. Alfalfa dwarf and Pierce's disease of grapevine are caused by the same virus. California Common 49 alfalfa is highly tolerant to the dwarf virus. Outbreaks of witches broom of alfalfa have occurred sporadically in seed fields of the Western States since 1925 when the disease was first recognized. Short rotations and elimination of old stands seem to be effective in controlling the disease.

Nematodes are widely distributed, but are destructive only in localized alfalfa-growing areas. The stem nematode thrives best under cool, moist conditions of spring and fall. It is most important where alfalfa is flood-irrigated in the West. The tiny, colorless, eellike worms responsible for the damage average about 1/20 inch in length and cause dwarfing of stems due to infected buds becoming thickened and deformed. The variety Nemastan is highly resistant to the stem nematode disease. The root-knot nematode frequently attacks alfalfa in regions where this parasite is abundant on other crops. It is most prevalent under conditions of mild climate, hence is of greatest concern in the South and Southwest. Characteristic symptoms are gall-shaped irregularities on roots. Very little attention has been given to this disease so its economic consequence to alfalfa has not been determined.

Control of Harmful Insects [5]

Several insects infest alfalfa and may cause damage to the hay or seed crop if not controlled. Measures recommended for control of these insects are given below.

Grasshoppers

Grasshoppers probably do more damage to alfalfa than any other insect. They attack the crop in all parts of the country, but are most often destructive in arid and semiarid regions. The species most commonly found on this crop are the red-legged grasshopper, the differential grasshopper, the lesser migratory grasshopper, and the two-striped grasshopper.

Insecticide sprays are effective in the control of grasshoppers on alfalfa. Use aldrin at 2 ounces, dieldrin at 1 ounce, chlordane at 1 pound, or toxaphene at 1½ pounds per acre.

When an entire field is severely infested with grasshoppers, it is ordinarily most economical to cut the alfalfa and then apply an insecticide to protect the next cutting. Spray field margins, ditchbanks, patches of weeds, or uncut strips of alfalfa where grasshoppers have concentrated. To control grasshoppers that hatch after the first crop has been harvested, spray the next crop before the new growth is more than 6 inches high.

For information on formulations, dosages, and methods of applying sprays and dusts for grasshopper control, consult your county agent or State agricultural experiment station.

Alfalfa Weevil

The alfalfa weevil now occurs in most of the Western States, in Nebraska and South Dakota, and in the Eastern States of Pennsylvania, New Jersey, Delaware, Maryland, and Virginia. The larvae feed on the growing tips, leaves, and buds of alfalfa and may destroy most of the feed value of a hay crop or prevent the profitable production of seed. The weevil is largely a pest of first-crop alfalfa. After the first hay crop is cut, however, the larvae feed upon the basal shoots and retard the second growth for a few days to several weeks. This is especially serious in dry-land farming or seed production.

In case of a severe infestation in alfalfa to be used for hay, it may be advisable to cut a little earlier than normal, probably when most of the plants are in the bud stage. However, such early harvest may impair the vigor of the stand, as discussed in the section, Harvesting and Meadow Management. When harvesting early for insect control, mow the field clean and remove the hay as soon as it is cured. Do not irrigate for 7 to 10 days after cutting. The immature stages of the larvae are killed by starvation and exposure to the sun.

Early-season chemical control of adult weevils on alfalfa grown for seed may be accomplished by a single application of ¼ pound of dieldrin or heptachlor or 1½ pounds of chlordane per acre in a spray when the spring growth is 1 to 2 inches tall. When the plants reach the bud stage, apply 2 pounds of DDT in a dust or 1½ pounds in a

[5] Contribution from the Section of Cereal and Forage Insect Investigations, Entomology Research Branch.

spray per acre. This treatment will control both weevil larvae and lygus bugs.

For early-season control of weevils on alfalfa grown for hay, kill the adults by making a single application of either dieldrin or heptachlor at the rate of ¼ pound per acre when the spring growth is 1 to 2 inches tall. An application of another insecticide may be necessary in May or June for control of the larvae. If so, dust or spray with 1½ pounds of methoxychlor or ¼ pound of parathion per acre as soon as plants become noticeably riddled but before many have turned gray.

Lygus Bugs

Lygus bugs feed on the buds, flowers, and seeds of alfalfa and may cause serious losses in yield of seed.

A single application of DDT as soon as the plants begin to bud will often give adequate protection. Use 25 pounds of 10-percent DDT dust or sufficient emulsion spray to give 1½ pounds of DDT per acre.

Sometimes alfalfa grown for seed may be reinfested during the bloom period to such a degree that a second application of insecticide is needed. If a second treatment is necessary, apply toxaphene before 7 a. m. or after 7 p. m., when few if any bees are working the flowers. Use sufficient spray to give 1½ pounds of toxaphene per acre. The best time for this application is 3 to 4 weeks after the bud-stage treatment with DDT.

Potato Leafhopper

The potato leafhopper is an important pest of alfalfa in the eastern part of the United States and as far west as Kansas. The adults cause yellowing, dwarfing, and even wilting of the plants, thus reducing the yield and quality of the crop.

This leafhopper can be controlled with methoxychlor applied in a spray at the rate of ½ pound per acre. Make the application when the crop is about half grown, or earlier if the insect becomes abundant.

A delay of 10 days to 2 weeks in cutting the first crop, if this does not lower the quality of the hay, will destroy large numbers of eggs and young leafhoppers which otherwise would mature and infest the next alfalfa crop.

Alfalfa Caterpillar

The alfalfa caterpillar commonly infests alfalfa grown for hay in the Southwest. Several natural enemies help to protect the crop from damage by this caterpillar. A virus disease that is present in the soil kills many larvae and pupae. Certain insect parasites and predators also aid in controlling the pest. Sometimes an insecticide is needed, however, to prevent serious and widespread damage. The need for an insecticide can be determined best by an experienced observer.

Methoxychlor is the only insecticide recommended. Apply it in a spray at ¾ pound per acre, or at 1 pound in hot desert areas. If large numbers of healthy caterpillars are seen in the field, cut the alfalfa close and clean before it becomes severely damaged. Where irrigation water is available, flood the field after the hay has been removed to kill any caterpillars left on the bare soil or short stubble.

Red Harvester Ant

The red harvester ant causes considerable damage to alfalfa in the Southwestern States. It destroys all the vegetation within a 3- to 5-foot radius around its nest. For most effective control, spread about ½ pound of 2-percent dieldrin or 5-percent chlordane dust thinly in a continuous band 4 to 6 inches wide, making a circle 5 to 6 feet in diameter in the cleared area around the nest entrance. The fumigants, carbon disulfide and methyl bromide, will also destroy nests of this ant.

Meadow Spittlebug

In recent years the spittlebug has become very abundant in the Northeastern and North Central States. In April, May, or early June the young, or nymphs, that hatch from overwintered eggs produce spittle in the crown or folded leaves of alfalfa. The nymphs live inside the spittle and suck the plant juices, stunting the plants and reducing the yield of forage.

This insect can be controlled with an insecticide. Spray within a week after the eggs begin to hatch, when the first small masses of froth can be seen on the alfalfa. Apply lindane at ¼ pound, methoxychlor at 1 pound, or toxaphene at 1½ pounds per acre.

Application of Insecticides

Insecticides may be applied either as dusts or sprays. Dusts are sold in different strengths and should be purchased ready-mixed. Spray formulations include high percentage concentrates prepared for emulsification with water or dilution with kerosene or fuel oil, and wettable powders prepared for dilution with water. Dilute to the strength that will give the recommended dosage of the insecticide. The dilution will vary with the type of spraying equipment used. Follow directions on the container carefully.

PRECAUTIONS: Insecticides are poisons. Handle them with care and store them, clearly labeled, out of reach of children and animals. Parathion is particularly dangerous and may be absorbed through the skin, eyes, lungs, or mouth. Persons handling it should wear a gas mask or respirator equipped with a canister of a type recommended by the United States Department of Agriculture. Parathion should be applied by persons experienced in handling poisonous chemicals.

If you apply DDT to alfalfa to control alfalfa weevil larvae or lygus bugs, or if you use chlordane for grasshopper control, do not feed the forage or chaff to dairy animals, animals being finished for slaughter, or poultry.

If you apply dieldrin or heptachlor for early-season control of alfalfa weevil adults, do not allow livestock to graze on the alfalfa until after the first cutting; if you use chlordane for the same purpose do not feed the first cutting to dairy animals or animals being finished for slaughter.

Do not allow animals to feed on alfalfa for 15 days after using aldrin or for 30 days after using dieldrin sprays for the control of grasshoppers.

Allow at least 40 days between the application of toxaphene to alfalfa and cutting or pasturing the crop. Apply lindane to alfalfa at least 2 weeks before cutting or pasturing it. Do not cut parathion-treated hay for at least 15 days after treatment.

Other Insects

A number of other insects may cause serious damage to alfalfa. The most important ones are the clover seed chalcid, the garden webworm, the clover root curculio, the pea aphid, the clover leaf weevil, the alfalfa looper, and the three-cornered alfalfa hopper. Alfalfa may also be attacked by various species of beetles, stink bugs, other leafhoppers, cutworms, and armyworms. Further information on the control of insect pests of alfalfa may be obtained from the United States Department of Agriculture, or from State agricultural experiment stations.

Rodents

The most troublesome animal pests encountered in growing a crop of alfalfa are gophers, ground squirrels, prairie dogs, and mice. They are especially troublesome in the western half of the country, where they eat the roots of the plants. Where irrigation waters are available these pests can be controlled to some extent by drowning. Poisoning and trapping are the best means of holding them in check, but because of the danger attending the careless use of poisons it is suggested that the farmer get in touch with the county agent, or a representative of the Fish and Wildlife Service, Department of the Interior, when these pests become troublesome.

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